APPARATUS FOR MANUFACTURING SEMI-SOLID METALLIC SLURRY

BACKGROUND OF THE INVENTION

This application claims the priority of Korean Patent Application No. 2003-48303, filed on July 15, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

1. Field of the Invention

The present invention relates to an apparatus for manufacturing a semi-solid metallic slurry, and more particularly, to an apparatus for manufacturing a semi-solid metallic slurry in a combined solid and liquid state that contains fine, uniform spherical particles.

2. Description of the Related Art

Semi-solid metallic slurries refer to metallic materials, in a combined solid and liquid phase, which are intermediates manufactured by thixoforming, also expressed as rheocasting/thixoforming. Semi-solid metallic slurries consist of spherical solid particles suspended in a liquid phase in an appropriate ratio at temperature ranges of a semi-solid state, and thus, they can be transformed even by a small force due to their thixotropic properties and can be easily cast like a liquid due to their high fluidity. Rheocasting refers to a process of manufacturing billets or final products from metallic slurries with a predetermined viscosity through casting or forging. Thixoforming refers to a process involving reheating billets, manufactured through rheocasting, back into semi-molten metallic slurries and casting or forging the metallic slurries to manufacture final products.

Such rheocasting/thixoforming is more advantageous than general forming processes using molten metals, such as casting or forging. Because semi-solid/semi-molten metallic slurries used in rheocasting/thixoforming have fluidity at a lower temperature than molten metals, it is possible to lower the die casting temperature, thereby ensuring an extended lifespan of the die. In addition, when semi-solid/semi-molten metallic slurries are extruded through a cylinder, turbulence is less likely to occur, and thus less air is incorporated during casting. Therefore, the formation of air pockets in final products is prevented. Besides, the

use of semi-solid/semi-molten metallic slurries leads to reduced shrinkage during solidification, improved working efficiency, mechanical properties, and anti-corrosion, and lightweight products. Therefore, such semi-solid/semi-molten metallic slurries can be used as new materials in the fields of automobiles, airplanes, and electrical, electronic information communications equipment.

As described above, semi-solid metallic slurries are used both in rheocasting and thixoforming. In detail, semi-solid slurries solidified from molten metals by a predetermined method are used in rheocasting, and semi-molten slurries obtained by reheating solid billets are used in thixoforming. Throughout the specification of the present invention, the term "semi-solid metallic slurries" means metallic slurries in a combined solid and liquid state at a temperature range between the liquidus temperature and the solidus temperature of the metals, which can be manufactured by rheocasting through solidification of molten metals.

In conventional rheocasting, molten metals are stirred at a temperature of lower than the liquidus temperature while cooling, to break up dendritic structures into spherical particles suitable for rheocasting, for example, by mechanical stirring, electromagnetic stirring, gas bubbling, low-frequency, high-frequency, or electromagnetic wave vibration, electrical shock agitation, etc.

By way of example, U.S. Patent No. 3,948,650 discloses a method and apparatus for manufacturing a liquid-solid mixture. In this method, molten metals are vigorously stirred while cooled for solidification. A semi-solid metallic slurry manufacturing apparatus disclosed in this patent uses a stirrer to induce flow of the solid-liquid mixture having a predetermined viscosity to break up dendritic crystalline structures or disperse broken dendritic crystalline structures in the liquid-solid mixture. In this method, dendritic crystalline structures formed during cooling are broken up and used as nuclei for spherical particles. However, due to generation of latent heat of solidification at the early stage of cooling, the method causes problems of low cooling rate, manufacturing time increase, uneven temperature distribution in a mixing vessel, and non-uniform crystalline structure. Mechanical stirring applied in the semi-solid metallic slurry manufacturing apparatus inherently leads to non-uniform temperature distribution in the mixing vessel. In addition, because the apparatus is operated in a chamber, it is difficult to continuously perform a subsequent process.

U.S. Patent No. 4,465,118 discloses a method and apparatus for manufacturing semi-solid alloy slurries. This apparatus includes a coiled electromagnetic field application unit, a cooling manifold, and a die, which are sequentially formed inward, wherein molten metals are continuously loaded down into the vessel, and cooling water is flowed through the cooling manifold to cool the outer wall of the die. In manufacturing semi-solid alloy slurries, molten metals are injected through a top opening of the die and cooled by the cooling manifold, thereby resulting in a solidification zone within the die. When a magnetic field is applied by the electromagnetic field application unit, cooling is allowed to break up dendritic crystalline structures formed in the solidification zone. Finally, ingots are formed from the slurries and then pulled through the lower end of the apparatus. The basic technical idea of this method and apparatus is to break up dendritic crystalline structures after solidification by applying vibration. However, many problems arise with this method, such as complicated processing and non-uniform particle structure. In the manufacturing apparatus, since molten metals are continuously supplied to grow ingots, it is difficult to control the states of the metal ingots and the overall process. Moreover, prior to applying an electromagnetic field, the die is cooled using water, so that a great temperature difference exists between the peripheral and core regions of the die.

Other types of rheocasting/thixoforming known in the art are described later. However, all of the methods are based on the technical idea of breaking up dendritic crystalline structures after formation, to generate nuclei of spherical particles. Therefore, problems arise, such as those described in conjunction with the above patents.

U. S. Patent No. 4,694,881 discloses a method for manufacturing thixotropic materials. In this method, an alloy is heated to a temperature at which all metallic components of the alloy are present in a liquid phase, and the resulting molten metals are cooled to a temperature between their liquidus and solidus temperatures. Then, the molten metals are subjected to a shearing force in an amount sufficient to break up dendritic structures formed during the cooling of the molten metals to thereby manufacture the thixotropic materials.

Japanese Patent Application Laid-open Publication No. Hei. 11-33692 discloses a method for manufacturing metallic slurries for rheocasting. In this method, molten metals are supplied into a vessel at a temperature near their liquidus

temperature or of 50℃ above their liquidus temperature. Next, when at least a portion of the molten metals reaches a temperature lower than the liquidus temperature, i.e., at least a portion of the molten metals begins with cooling below their liquidus temperature, the molten metals are subjected to a force, for example, ultrasonic vibration. Finally, the molten metals are slowly cooled into the metallic slurries containing spherical particles. This method also uses a physical force, such as ultrasonic vibration, to break up the dendrites grown at the early stage of solidification. In this regard, if the casting temperature is greater than the liquidus temperature, it is difficult to form spherical particle structures and to rapidly cool the molten metals. Furthermore, this method leads to non-uniform surface and core structures.

Japanese Patent Application Laid-open Publication No. Hei. 10-128516 discloses a casting method of thixotropic metals. This method involves loading molten metals into a vessel and vibrating the molten metals using a vibrating bar dipped in the molten metals to directly transfer its vibrating force to the molten metals. After forming a semi-solid and semi-liquid molten alloy, which contains nuclei, at a temperature range lower than its liquidus temperature, the molten alloy is cooled to a temperature at which it has a predetermined liquid fraction and then left stand from 30 seconds to 60 minutes to allow the nuclei to grow, thereby resulting in thixotropic metals. However, this method provides relatively large particles of about 100 μm and takes a considerably long processing time, and cannot be performed in a vessel larger than a predetermined size.

U.S. Patent No. 6,432,160 discloses a method for making thixotropic metal slurries. This method involves simultaneously controlling the cooling and the stirring of molten metals to form the thixotropic metal slurries. In detail, after loading molten metals into a mixing vessel, a stator assembly positioned around the mixing vessel is operated to generate a magnetomotive force sufficient to rapidly stir the molten metals in the vessel. Next, the molten metals are rapidly cooled by means of a thermal jacket, equipped around the mixing vessel, for precise temperature control of the mixing vessel and the molten metals. During cooling, the molten metals are continuously stirred in a manner such that when the solid fraction of the molten metals is low, a high stirring rate is provided, and when the solid fraction increases, a greater magnetomotive force is applied.

Most of the aforementioned conventional methods and apparatuses for manufacturing semi-solid metal slurries use shear force to break dendritic structures into spherical structures during a cooling process. Since a force such as vibration is applied after at least a portion of the molten metals is cooled below their liquidus temperature, latent heat is generated due to the formation of initial solidification layers. As a result, there are many disadvantages such as reduced cooling rate and increased manufacturing time. In addition, due to a non-uniform temperature between the inner wall and the center of the vessel, it is difficult to form fine, uniform spherical metal particles. Therefore, this structural non-uniformity of metal particles will be greater if the temperature of the molten metals loaded into the vessel is not controlled.

SUMMARY OF THE INVENTION

The present invention provides an apparatus for manufacturing a semi-solid metallic slurry containing fine, uniform spherical particles, with improvements in energy efficiency and mechanical properties, cost reduction, convenience of casting, and shorter manufacturing time.

The present invention also provides an apparatus for manufacturing a high-quality semi-solid metallic slurry within a short period of time, which can be readily and conveniently applied to a subsequent process.

The present invention also provides an apparatus for manufacturing and discharging a high-quality semi-solid metallic slurry in a convenient manner.

According to an aspect of the present invention, there is provided an apparatus for manufacturing a semi-solid metallic slurry, the apparatus comprising: at least one sleeve with two open ends, through one of which molten metal in liquid state is loaded into the sleeve; a stirring unit which applies an electromagnetic field to the molten metal in the sleeve; and a shutter unit which closes the other end of the sleeve to form a base of the sleeve and opens the base of the sleeve to discharge a slurry after manufacture from the sleeve.

According to specific embodiments of the present invention, the shutter unit may be a stopper fixed to the other end of the sleeve. The shutter unit may be a plunger inserted into the other end of the sleeve and moved up and down. The apparatus may further include a pressing unit inserted into the one end of the sleeve to press the slurry in the sleeve down. In the apparatus, the molten metal in the

sleeve may be cooled until the molten metal has a solid fraction of 0.1-0.7. In this case, the apparatus may further include a temperature control element to control the temperature of the molten metal during cooling.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a graph of temperature versus time when a semi-solid metallic slurry is manufactured with an apparatus according to the present invention;

FIG. 2 illustrates the structure of an apparatus for manufacturing a semi-solid metallic slurry according to an embodiment of the present invention;

FIG. 3 is a sectional view of an example of a sleeve used in a semi-solid metallic slurry manufacturing apparatus according to the present invention;

FIG. 4 illustrates discharge of a semi-solid metallic slurry from the semi-solid metallic slurry manufacturing apparatus of FIG. 2;

FIG. 5 illustrates the structure of a semi-solid metallic slurry manufacturing apparatus according to another embodiment of the present invention that further includes a pressing unit compared to the apparatus of FIG. 2;

FIG. 6 illustrates the structure of a semi-solid metallic slurry manufacturing apparatus according to another embodiment of the present invention;

FIG. 7 illustrates discharge of a semi-solid metallic slurry from the semi-solid metallic slurry manufacturing apparatus of FIG. 6; and

FIG. 8 illustrates the structure of a semi-solid metallic slurry manufacturing apparatus according to another embodiment of the present invention that further includes a pressing unit compared to the apparatus of FIG. 6.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be described in detail with reference to the appended drawings.

First, a method of manufacturing a semi-solid metallic slurry using an apparatus according to the present invention will be described with reference to FIG. 1.

Unlike the aforementioned conventional techniques, a method of manufacturing a semi-solid metallic slurry using the apparatus of the present invention involves stirring molten metals by applying an electromagnetic field prior to the completion of loading the molten metals into a sleeve. In other words, electromagnetic stirring is performed prior to, simultaneously with, or in the middle of loading the molten metals into the sleeve, to prevent the formation of dendritic structures. The stirring process may be performed using ultrasonic waves instead of the electromagnetic field.

First, after an electromagnetic field is applied to at least one sleeve surrounded by a stirring unit, a molten metal is loaded into the sleeve. The intensity of the applied electromagnetic field is strong enough to stir the molten metal.

As shown in FIG. 1, the molten metal is loaded into the sleeve at a temperature Tp. As described above, an electromagnetic field may be applied to the sleeve prior to the loading of molten metal into the sleeve. However, the present invention is not limited to this, and electromagnetic stirring may be performed at the start of in the middle of loading the molten metal into the sleeve.

Due to the electromagnetic stirring performed prior to the completion of loading molten metal into the sleeve, the molten metal does not grow into dendritic structures near the inner wall of the low temperature sleeve at the early stage of solidification, and numerous micronuclei are concurrently generated throughout the sleeve because the temperature of the entire molten metal is rapidly dropped to a temperature lower than its liquidus temperature.

Applying an electromagnetic field to the sleeve prior to or simultaneously to loading molten metal into the sleeve leads to active stirring of the molten metal in the center and the inner wall regions of the sleeve and rapid heat transfer throughout the sleeve. Therefore, the formation of solidification layers near the inner wall of the sleeve at the early stage of cooling is prevented. In addition, such active stirring of the molten metal induces smooth convection heat transfer between the higher temperature molten metal and the lower temperature inner sleeve wall. Therefore, the molten metals can be rapidly cooled. Due to the electromagnetic stirring, particles contained in the molten metals scatter upon loading the molten metal into the sleeve and are dispersed throughout the sleeve as nuclei, so that only a minor temperature difference occurs in the sleeve during cooling. However, in conventional techniques, the temperature of the molten metal suddenly drops as

soon as it contacts the lower temperature inner vessel wall, so that dendritic crystals grow from solidification layers formed near the inner wall of the vessel at the early stage of cooling.

The principles of the present invention will become more apparent when described in connection with latent heat of solidification. Molten metal does not solidify near the inner sleeve wall at the early stage of cooling, and no latent heat of solidification is generated. Accordingly, the amount of heat to be dissipated from the molten metal for cooling is equivalent only to the specific heat of the molten metal, which corresponds to about 1/400 of the latent heat of solidification. Therefore, dendrites, which are generated frequently near the inner sleeve wall at the early stage of cooling when using conventional methods, are not formed, and the entire molten metal in the sleeve can be uniformly cooled. It takes merely about 1-10 seconds from the loading of the molten metal. As a result, numerous nuclei are created and dispersed uniformly throughout the entire molten metal in the sleeve. The increased density of nuclei shortens the distance between the nuclei, and spherical particles instead of dendritic particles are formed.

The same effects can even be achieved even when an electromagnetic field is applied in the middle of loading the molten metal into the sleeve. In other words, solidification layers are hardly formed near the inner sleeve wall even when electromagnetic stirring begins in the middle of loading the molten metal into the sleeve.

It is preferable to limit the loading temperature, Tp, of the molten metal to a range from its liquidus temperature to 100℃ above the liquidus temperature (melt superheat = 0~100℃). According to the present invention, since the entire sleeve containing the molten metal is uniformly cooled, there is no need to cool the molten metal to near their liquidus temperature. Therefore, it is possible to load the molten metal into the sleeve at a temperature of 100℃ above its liquidus temperature.

On the other hand, in conventional methods, an electromagnetic field is applied to a vessel after the completion of loading molten metal into the vessel and a portion of the molten metal reaches below its liquidus temperature. Accordingly, latent heat is generated due to the formation of solidification layers near the inner wall of the vessel at the early stage of cooling. Because the latent heat of solidification is about 400 times greater than the specific heat of the molten metal, considerable time is required to drop the temperature of the entire molten metal

below its liquidus temperature. Therefore, in such conventional methods, the molten metal is loaded into a vessel, in general, after the molten metal is cooled to a temperature near its liquidus temperature or to a temperature of 50℃ above its liquidus temperature.

According to the present invention, the electromagnetic stirring may be stopped at any point after at least a portion of the molten metal in the sleeve reaches a temperature lower than the liquidus temperature T_l, i.e., after accomplishing nucleation for a solid fraction of, for example, about 0.001, as illustrated in FIG. 1. For example, an electromagnetic field may be applied to the molten metal in the sleeve throughout the cooling process of the molten metal, but prior to a subsequent molding process such as die casting or hot forging. This is because, once nuclei are distributed uniformly throughout the sleeve, even at the time of growth of crystalline particles from the nuclei, properties of the metallic slurry are not affected by the electromagnetic stirring. Therefore, the electromagnetic stirring can be sustained until a solid fraction of the molten metal reaches at least 0.001-0.7. However, in view of energy efficiency, the electromagnetic stirring is carried out until a solid fraction of the molten metal reaches the range of, preferably, 0.001-0.4, and more preferably, 0.001-0.1.

After the electromagnetic stirring is completed, the metallic slurry is discharged from the sleeve for a continuous subsequent process, for example, die casting, hot forging, and billet formation.

After an electromagnetic field is applied prior to the completion of loading the molten metal into the sleeve for uniform nucleation throughout the sleeve, the sleeve is cooled to accelerate the growth of the nuclei. This cooling process may be performed simultaneously to loading the molten metal into the sleeve.

As described above, the application of the electromagnetic field may be sustained throughout the cooling process. In other words, cooling may be performed while the electromagnetic field is applied to the sleeve. As a result, a resulting semi-solid metallic slurry can be immediately used in a subsequent forming process.

The cooling process may be sustained just prior to a subsequent forming process, preferably, until the solid fraction of the molten metals reaches 0.1-0.7, i.e., up to time t_2 of FIG. 1. The molten metal may be cooled at a rate of 0.2-5.0℃/sec,

preferably, 0.2-2.0℃/sec depending on a desired distribution of nuclei and a desired size of particles.

A semi-solid metallic slurry containing a predetermined amount of solid is manufactured through the above-described processes and readily subjected to billet formation by rapid cooling, for thixoforming, or die casting, forging, or pressing to form final products.

According to the present invention described above, a semi-solid metallic slurry can be manufactured within a short period of time, merely in 30-60 seconds from loading the molten metal into the sleeve for a metallic slurry with a solid fraction of 0.1-0.7. In addition, the manufactured metallic slurry can be molded into products having a uniform, dense spherical crystalline structure.

The aforementioned method of manufacturing a semi-solid metallic slurry can be performed using an apparatus according to an embodiment of the present invention as shown in FIGS. 2 and 3.

Referring to FIG. 2, a semi-solid metallic slurry manufacturing apparatus according to an embodiment of the present invention includes at least one sleeve 2 with two open ends, through one of which molten metal in liquid state is loaded; a stirring unit 1 which applies an electromagnetic field to the molten metal; and at least one shutter) unit 3 which closes the other end of the sleeve 2 to form a base of the sleeve 2 and opens the base of the sleeve 2 to discharge a slurry manufactured therein.

The stirring unit 1 is mounted on the top of a hollow base plate 14. The base plate 14 is supported by a support member 15 at a predetermined height above the ground. A coil 11 for applying an electromagnetic field is mounted on the base plate 14, while being supported by a frame 12 having an inner space 13. The coil 11 is electrically connected to a controller (not shown) and applies a predetermined intensity of electromagnetic field toward the space 13 to electromagnetically stir the molten metal contained in the sleeve 2 placed in the space 13. Although not shown in FIG. 2, the stirring unit 1 may be an ultrasonic stirrer.

As shown in FIG. 2, the sleeve 2 may be placed inside the stirring unit 1, i.e., in the space 13. The sleeve 2 may be fixed on the base plate 14 in contact with the frame 12. The sleeve 2 may be made of a metallic material or an insulating material. However, it is preferable to use the sleeve 2 made of a material having a higher melting point than the molten metal to be loaded thereinto. The lower end of

the sleeve 2 is closed or opened by the shutter unit 3 and the upper end of the sleeve 2 is open for receiving molten metal. That is, the sleeve 2 may be a vessel with the shutter unit 3 at its bottom. However, there are no particular limitations to the structure of the sleeve 2, provided that its bottom can be closed or opened with the shutter unit 3. Although not shown in FIG. 2, a thermocouple may be installed in the sleeve 2 and connected to a controller to provide temperature information.

The apparatus according to the present invention may further include a temperature control element 20 that is installed around the sleeve 2, as shown in FIG. 3. The temperature control element 20 is comprised of a cooler and/or a heater. In the embodiment of FIG. 3, a water jacket 22 acts as a cooler and an electric heating coil 23 acts as a heater. The water jacket 22 is installed around the sleeve 2 and contains a cooling water pipe 21. The electric heating coil 23 is installed around the water jacket 22. The cooling water pipe 21 may be laid in the sleeve 2, and other heating means, in addition to the electric heating coil 23, may be used for the heater. There are no particular limitations to the structure of the temperature control element 20, provided that it can adjust the temperature of molten metal or slurry. Molten metal contained in the sleeve 2 can be cooled at an appropriate rate using the temperature control element 20. It is understood that such a sleeve 2 can be applied to all of the following embodiments of a semi-solid metallic slurry manufacturing apparatus according to the present invention. Cooling means for the molten metal contained in the sleeve 2 are not limited to the temperature control element 20, and the molten metal in the sleeve 2 may be cooled naturally.

The shutter unit 3 forming the base of the sleeve 2 may have any structure capable of opening and closing the bottom of the sleeve 2. In an embodiment of the semi-metallic slurry manufacturing apparatus according to the present invention, the shutter unit 3 may be implemented with a stopper 31, as illustrated in FIG. 2. The stopper 31 can be moved by a driving apparatus (not shown) to close or open the bottom of the sleeve 2, as shown in FIGS. 2 and 4. The stopper 31 may be made of the same material as the sleeve 2. Alternatively, the stopper 31 may be formed as a hinged door.

In addition, although not shown in the drawings, the shutter unit 3 may be removed downward along with a slurry discharged from the slurry manufacturing apparatus. In other words, when discharging a slurry after manufacture, the shutter

unit 3 is detached from the sleeve 2 in the downward direction to support the dropping slurry.

A loading unit 4 is a means for providing molten metal into the sleeve 2. As for the loading unit 4, a general ladle, which is electrically connected to the controller, may be used. In addition, a furnace where the molten metal is prepared may be directly connected to the sleeve 4. Any devices for loading molten metal into the sleeve 2 can be used as the loading unit 4.

In a semi-solid metallic slurry manufacturing apparatus according to the present invention having such a structure described above, as shown in FIG. 2, after the stopper 31 is fitted to the bottom of the sleeve 2, an electromagnetic field having a predetermined frequency is applied to the sleeve 2 at a predetermined intensity by the stirring unit 1. Next, metal M, which has melted in a separate electric furnace, is loaded via the loading unit 4 into the sleeve 2 under the electromagnetic field. Instead of applying the electromagnetic field prior to the loading of the molten metal into the sleeve, the electromagnetic field can be applied to the sleeve 2 simultaneously to or in the middle of loading the molten metal M into the sleeve 2, as described above.

After the molten metal is loaded into the sleeve 2, the molten metal in the sleeve 2 is cooled at a predetermined rate until the solid fraction of a resultant semi-solid metallic slurry S reaches the range of 0.1-0.7. The cooling rate may be in a range of, preferably, 0.2-5.0℃/sec, and more preferably 0.2-2.0℃/sec, as described above. The cooling may be carried out with the temperature control element 20, without it, or with some other cooling means. It will be appreciated that the molten metal contained in the sleeve 2 may be naturally cooled without the aid of the temperature control element 20.

Meanwhile, the application of an electromagnetic field may be sustained until the completion of cooling, i.e., the solid fraction of the resultant semi-solid metallic slurry reaches the range of at least 0.001-0.7. In view of energy efficiency, the application of an electromagnetic field may be sustained after loading the molten metal into the sleeve 2 until the solid fraction reaches, preferably, at least 0.001-0.4, and more preferably, 0.001-0.1. The time required for these solid fraction levels can be previously determined through experiments. It will be appreciated that cooling can be performed while the electromagnetic field is applied to the sleeve 2, as described above.

After the slurry S is manufactured, the stopper 31 is moved to open the bottom of the sleeve 2 so that the slurry S is discharged through the bottom of the sleeve 2 due to gravity. An external transfer unit (not shown) may be installed near the bottom of the sleeve 2 to transfer the slurry S to a molding apparatus for subsequent rheocasting. Alternatively, although not illustrated, a cooler-equipped sleeve may be further installed at the bottom of the sleeve 2 to immediately mold the discharged slurry S into billets. A casting die for die-casting and other forming apparatuses may be further installed at the bottom of the sleeve 2 to process the discharged slurry S into products.

In addition to the embodiment of the semi-metallic slurry manufacturing apparatus shown in FIGS. 2 and 4 where the manufactured slurry S is discharged from the sleeve 2 due to gravity, the slurry S may be discharged by force applied by a pressing unit 5, as shown in FIG. 5.

In an embodiment of the semi-metallic slurry manufacturing apparatus according to the present invention shown in FIG. 5, the pressing unit 5, which is connected to a driving unit (not shown), is inserted into the upper end of the sleeve 2. Any pressing means capable of pushing the content of the sleeve 2, such as molten metal or slurry, downward can be used for the pressing unit 5. An example of a pressing means is a plunger 51. The plunger 51 may be separated from the sleeve 2 when molten metal is loaded into the sleeve 3 and inserted into the upper end of the sleeve 2 after the loading of the molten metal into the sleeve 2. After a semi-metallic slurry is manufactured and the stopper 31 is removed from the bottom of the sleeve 2, the semi-metallic slurry is pushed by the plunger 2 and discharged from the sleeve 1.

FIGS. 6 through 8 illustrate other embodiments of the semi-metallic slurry manufacturing apparatus according to the present invention, in which a plunger 32 is inserted into the lower end of the sleeve 2 as a shutter unit 3. In particular, the plunger 32 is inserted into the lower end of the sleeve 2 by operating a separate driving unit (not shown) prior to loading molten metal M into the sleeve 2. After the manufacture of slurry S, the plunger 32 is removed downward from the sleeve 2 to discharge the slurry S from the sleeve 2, as shown in FIG. 7. In another embodiment of the present invention, a transfer unit (not shown), such as a robotic apparatus, may be further used to stably transfer the discharged slurry S supported on the plunger 32 for a subsequent process.

In addition, the pressing unit 5, such as the plunger 51 shown in FIG. 5, may be further inserted into the upper end of the sleeve 2, as illustrated in FIG. 8, to press the slurry S in the sleeve 2 downward.

A large amount of semi-metallic slurry can be manufactured continuously with one of the semi-solid metallic slurry manufacturing apparatuses according to the present invention described above with more convenience when applied to a subsequent process and enhanced overall processing efficiency. In addition, a manufactured slurry can be easily discharged from the apparatus through the bottom of the sleeve.

The apparatus for manufacturing a semi-solid metallic slurry according to the present invention is compatible with various kinds of metals and alloys, for example, aluminum, magnesium, zinc, copper, iron, and alloys thereof, for rheocasting. A semi-solid metallic slurry manufactured with the apparatus according to the present invention contain spherical microparticles of uniform distribution with an average diameter of 10-60 μ m.

As described above, metallic slurries with improved mechanical properties that contain uniform, micro, spherical particles can be manufactured with the apparatus according to the present invention. According to the present invention, uniform, spherical particles can be formed within a short time through electromagnetic stirring initiated at a temperature above the liquidus temperature of the molten metal to generate more nuclei in the sleeve.

When using a semi-solid metallic slurry manufacturing apparatus according to the present invention, the overall slurry manufacturing process can be simplified, and the duration of electromagnetic stirring and molding (casting) time can be greatly shortened, thereby saving energy for the stirring and costs. The semi-solid metallic slurry manufacturing apparatus according to the present invention makes it convenient to perform a subsequent process and increases the yield of molded products.

The semi-solid metallic slurry manufacturing apparatus according to the present invention allows a manufactured slurry to be discharged easily with a simple structure, so that a large amount of semi-solid slurry can be rapidly and conveniently manufactured

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of

ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.